

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
28 February 2002 (28.02.2002)

PCT

(10) International Publication Number  
**WO 02/17384 A1**

(51) International Patent Classification<sup>7</sup>: **H01L 21/68, 21/00**, HARVEY, Stefanie; 1008 North Sixth Street, San Jose, CA 95112 (US).

(21) International Application Number: **PCT/US01/41838** (74) Agents: **BERNADICOU, Michael, A. et al.**; Blakely, Sokoloff, Taylor & Zafman LLP, 7th floor, 12400 Wilshire Boulevard, Los Angeles, CA 90025 (US).

(22) International Filing Date: 21 August 2001 (21.08.2001)

(25) Filing Language: English

(81) Designated States (*national*): CN, JP, KR, SG.

(26) Publication Language: English

(84) Designated States (*regional*): European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

(30) Priority Data:  
09/645,032 23 August 2000 (23.08.2000) US

Published:

- *with international search report*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

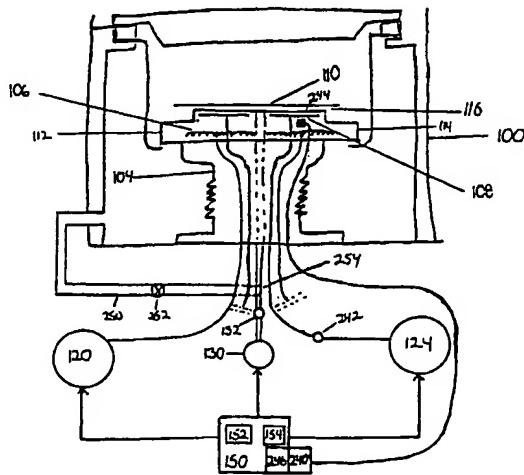
(71) Applicant: **APPLIED MATERIALS, INC. [US/US]; P.O. Box 450A, Santa Clara, CA 95052 (US).**

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(72) Inventors: KHURANA, Nitin; 568 Glasgow Court, Milpitas, CA 95035 (US). TZOU, Eugene; 1162 Woodborough Place, San Jose, CA 95116 (US). PARKHE, Vijay, D.; 4054 Bouquet Park Lane, San Jose, CA 95135 (US).

---

(54) Title: ELECTROSTATIC CHUCK TEMPERATURE CONTROL METHOD AND SYSTEM



(57) Abstract: A method and system are provided for controlling temperature of a substrate (110) retained by an electrostatic chuck (112) by varying the voltage supplied to the electrode(s) (108) of the electrostatic chuck. The voltage is decreased to increase the gap (116) between the wafer and the chuck and the voltage is increased to decrease the gap. The rates of heat transfer by radiation, conduction, and convection are correspondingly modified. A heat transfer gas is preferably supplied to the gap and maintained at relatively constant pressure. The pressure of the heat transfer gas can be independently varied at the same time as the chucking voltage to permit an additional level of temperature control. Alternatively, the pressure of heat transfer gas can be modified in response to the dimensions of the gap. The varying of the chucking voltage and/or heat transfer gas pressure can be performed in response to a feedback of measured parameter data from the substrate.

WO 02/17384 A1

## ELECTROSTATIC CHUCK TEMPERATURE CONTROL METHOD AND SYSTEM

TECHNICAL FIELD

5        The present invention relates generally to a method and system for temperature control of a substrate in a vacuum processing chamber and, more specifically, to a method and system for aluminum planarization of a semiconductor wafer in a semiconductor wafer processing system.

10      BACKGROUND ART

The various semiconductor wafer fabrication processes are typically performed under precise conditions in a controlled environment such as a vacuum process chamber. Figure 1 is a cross-sectional view of a wafer processing chamber 100 according to the 15 prior art. During wafer processing, the wafer 110 rests on a supporting pedestal 104 and is secured thereto by a mechanical clamp (not shown) or by an electrostatic chuck 112.

Electrostatic chucks contain one or more electrodes 108 that are embedded within a chuck body 114 formed of a dielectric material such as ceramic or polyimide. Such electrostatic chucks are described in, for example, U.S. Pat. No. 4,184,188, to 20 Briglia ("the '188 patent"), incorporated herein by reference. A voltage from a power supply 124 is applied to the electrode(s) to electrostatically attract the wafer to the chuck. This voltage must be sufficiently high to prevent the wafer from moving during processing, for example in response to vibration or the force of a back side heat transfer gas. However, the voltage also must be sufficiently low for reasons including preventing 25 the wafer from breaking or warping, and preventing the production of excessive contaminating particles.

The various wafer fabrication processes and/or steps thereof may require significantly different operating conditions. A process software application, known as a "recipe" can be stored in at least one memory 154 and includes process system 30 parameter requirements such as chamber pressure, temperature, and the times and durations of any parameter modifications. The system parameters of the fabrication

process are controlled in accordance with the recipe in response to process control signals from a process control module 150 associated with the memory. The process control module also typically includes a central processing unit ("CPU") 152 as well as other well-known hardware and software components.

5        A significant factor in assuring accuracy and efficiency in the manufacture of semiconductor devices is the consistency or uniformity of processing conditions. For example, in temperature sensitive processes such as aluminum planarization, the temperature across the surface of a semiconductor wafer must be maintained within a specific range to minimize process degradation. Aluminum planarization is discussed  
10      generally in commonly assigned U.S. Pat. No. 5,467,220 to Xu ("the '220 patent"), incorporated by reference herein. As disclosed in the '220 patent, the failure, in a hot aluminum planarization process, to provide a high degree of temperature consistency across the wafer surface can result in poor planarization of the aluminum film.

15      Various structures and methods have been used to improve temperature control across the face of a wafer during processing. For example, the '188 patent describes wafer temperature control through heat transfer between the wafer and the chuck. To further promote such heat transfer, a channel (not shown) containing a fluid for cooling the pedestal can be disposed therein. In some systems, one or more heaters 106 are disposed within the pedestal for use in heating a wafer secured to the electrostatic chuck.  
20      Such heater can be controlled by a heater control module 120, responsive to manual control or to a signal from the process control module.

25      As a result of surface roughness, the actual area of contact between the back side surface of the wafer and the chuck surface is relatively small. To improve heat transfer, a gas such as helium or argon can be supplied to the gap 116 between the chuck and the wafer to facilitate heat transfer by conduction and convection in addition to radiant heat transfer. The effectiveness of such back side gas heat transfer depends in large part on the ability of the gas to flow behind the wafer as well as on the distance between the chuck surface and the wafer. Therefore, to achieve a desired wafer temperature profile, different chuck surface configurations have been used to vary the amount of chuck-to-  
30      wafer contact as well as the distance between the wafer and the chuck. For example, a

grooved electrostatic chuck surface is described in commonly assigned U.S. Pat. 5,522,131, to Steger, incorporated by reference herein.

The pressure and flow rate of the heat transfer gas can be varied to increase or decrease the heat transfer between the wafer and the chuck. In the prior art systems, this  
5 is accomplished, for example, using a mass flow controller 132 responsive to the process control signals of the process control module 150 to vary the amount and flow rate of gas supplied to the backside region from the gas supply 130. However, while the amount and flow rate of the gas can be varied in the prior art systems, once the wafer has initially been electrostatically attracted to the chuck, the distance(s) between the wafer  
10 and the chuck remains relatively constant throughout the fabrication process. As a result, the rate of increase or decrease ("ramp") of wafer temperature is limited consistent with the known properties of the heat transfer gas and the fixed distance between the wafer and the chuck.

It would therefore be an advantage to provide a method and system for varying  
15 the distance between the wafer and the pedestal during processing to modify wafer temperature. It would be a further advantage if such method and system were adapted for use with other temperature control methods and systems to provide an additional level of temperature control. It would be yet another advantage if such method and system permitted the rapid ramping of wafer temperature during processing.

SUMMARY AND OBJECTS OF THE INVENTION

The present invention is a method and system for controlling temperature of a substrate retained by an electrostatic chuck in a vacuum process chamber. The method and system according to the present invention is preferably applied to a semiconductor wafer processing system and, more specifically, to an aluminum planarization process. The method and system described herein can be used with an electrostatic chuck having any appropriate surface configuration.

In the invention, a power supply control module is used to vary the voltage supplied to the electrode(s) of the electrostatic chuck during processing. As the chucking voltage is decreased, the electrostatic chucking force attracting the wafer to the chuck is decreased and the gap between the back side surface of the wafer and the chuck is correspondingly increased. Conversely, as the chucking voltage is increased, the electrostatic chucking force is increased and the gap between the wafer back side surface and the chuck is correspondingly decreased.

In the preferred embodiment of the present invention, a heat transfer gas is supplied to the gap during processing to facilitate heat transfer between the chuck and the wafer. The heat transfer gas is preferably maintained at a relatively constant pressure through use of a needle valve. In alternative embodiments, as a result of heat transfer gas leakage, an increase in gap size results in decreased back side gas pressure and a decrease in gap size results in increased back side gas pressure. Because heat transfer between the wafer and the chuck is dependent upon both the distance therebetween and the heat transfer gas pressure, the rates of heat transfer by radiation, conduction, and convection are varied with the changes in gap size and heat transfer gas pressure, in accordance with well-known principles of fluid heat transfer.

The amount and flow rate of the heat transfer gas can be varied at the same time as the chucking voltage to permit an additional level of temperature control. The amount and flow rate of the heat transfer gas is preferably controlled independently of the chucking voltage by any well-known control mechanism. Alternatively, the heat transfer gas can be controlled in conjunction with the voltage control.

While, in the preferred embodiment, the variations in the voltage and/or the heat transfer gas are experimentally determined in advance of processing and are incorporated into the process recipe, in an alternative embodiment, a feedback mechanism is used to dynamically control the voltage and/or heat transfer gas. In this 5 embodiment, a parameter sensor, such as a temperature sensor and/or a pressure sensor, is used to measure the process conditions at the back side surface of the wafer. The measured parameter data is transmitted to a feedback control module associated with the power supply control module. The power supply control module issues process control signals in response to the measured parameter data to vary process conditions included 10 but not limited to the chucking voltage, back side gas pressure, heat transfer gas leakage and any combinations thereof to achieve a desired temperature or temperature profile of the wafer.

The voltage variation according to the present invention provides an additional level of temperature control over the prior art methods and permits rapid temperature 15 ramping. The variations in wafer temperature ramp rate that can be achieved using the present invention can be of advantage in numerous processes and conditions, including but not limited to aluminum planarization, chemical vapor deposition, physical vapor deposition, metal deposition, etching, annealing, BSGP, to minimize the effects of outgassing, and to increase or decrease the absorption of ions or molecules by the wafer.

20 The varying of chucking voltage according to the present invention can also be used to control the time required to perform a particular step or process. In addition, decreasing the voltage supplied to the electrostatic chuck can also reduce the time required to dechuck a wafer. This can be of advantage in decreasing wafer throughput time for the fabrication process.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 is a cross-sectional view of a wafer processing chamber according to the prior art.

5 Figure 2 is a cross-sectional view of a wafer processing chamber according to the present invention.

Figure 3 is a graph of wafer temperature ramp rate according to the present invention.

10 Figure 4 is a graph of wafer temperature vs. time vs. backside gas pressure in an aluminum planarization process according to the present invention.

Figure 5 is a graph of electrostatic chuck backside gas pressure and dechucking time for various chucking voltages according to the present invention.

DISCLOSURE OF INVENTION

15

The present invention is a method and system for controlling temperature of a substrate retained by an electrostatic chuck in a vacuum process chamber. In the invention, voltage variation is used to change the distance between the substrate and the chuck, thereby providing an additional level of temperature control over the prior art methods and permitting rapid temperature ramping. The present invention can be used in conjunction with any other appropriate method for controlling the temperature of a substrate, including but not limited to use of heat transfer fluid channels disposed within the pedestal, use of a heater disposed within the pedestal, controlling the temperature of heat transfer gas, controlling the flow of heat transfer gas, controlling the pressure of heat transfer gas, and controlling the leakage of heat transfer gas into the vacuum process chamber, or any combinations thereof.

20  
25  
30 The method and system according to the present invention is preferably applied to a semiconductor wafer processing system such as that illustrated by Figure 1. However, one of skill in the art will readily recognize that the invention described herein can additionally be applied to any electrostatic holding system, process, or substrate for

which temperature control is required. In addition, the invention can be used with both monopolar and bipolar electrostatic chucks.

In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be evident, however, to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well-known structures and devices are shown in block diagram form to facilitate explanation. The description of preferred embodiments is not intended to limit the scope of the claims appended hereto.

Figure 2 is a sectional view of a wafer processing chamber according to the present invention. The invention is best understood as applied to a hot aluminum planarization process. However, the invention can also be applied to other wafer fabrication processes in which substrate temperature control is desirable, including but not limited to etch and deposition processes.

At the commencement of the exemplary aluminum planarization process, the wafer is electrostatically attracted to the chuck and the wafer back side region is pressurized to control the wafer temperature during a seed layer deposition step. Aluminum has a relatively low melting point and degrades above a certain temperature range. In certain types of aluminum planarization processes, wafer temperature is maintained at a level below 180 - 200° C during the seed layer deposition step to avoid degradation of the aluminum. In accordance with the process recipe, once the seed layer has reached a selected thickness on the top surface of the wafer, a heater(s) disposed within the pedestal is used to heat the wafer to the desired temperature for a fill step. It is at this step that heat transfer gas is supplied to the wafer back side region to facilitate the transfer of heat from the heater to the wafer. The heated aluminum then flows into the structures over the wafer to form a planar surface.

Wafer temperature during processing can be controlled by controlling the temperature of the heater. Furthermore, because the temperature of the wafer is also dependent upon the transfer by the heat transfer gas of heat from the heater, the wafer temperature can also be controlled by manipulating the rate of heat transfer. This can be

accomplished by controlling the amount and flow rate of the heat transfer gas to manipulate the pressure of the back side heat transfer gas.

However, the invention additionally includes the functionality to permit changing the distance between the wafer and the electrostatic chuck and heater. This is

- 5       accomplished by varying the voltage supplied from the power supply to the electrode(s) of the electrostatic chuck. In the presently preferred embodiment, a power supply control module 246 is used to vary the voltage supplied to the electrodes. The power supply control module is preferably associated with and directed in response to the process control module, but can alternatively be independent thereof.

- 10      As the chucking voltage is decreased, the electrostatic chucking force attracting the wafer to the chuck is decreased and the distance between the back side surface of the wafer and the chuck is correspondingly increased. Because the heat transfer between the wafer and the pedestal (*i.e.* heaters) is dependent, in part, on the distance and amount of surface-to-surface contact between the wafer and the chuck, the rate of heat transfer  
15      between the wafer and pedestal is decreased in accordance with well-known scientific principles of heat transfer.

- In the preferred embodiment, a heat transfer gas is also supplied to the wafer back side region. In this preferred embodiment, there is a minimal amount of leakage of heat transfer gas from the wafer back side region. The amount and flow rate of the back  
20      side heat transfer gas is maintained relatively constant and leakage is controlled using a needle valve (described in further detail, below). As a result, the pressure of the heat transfer gas remains relatively constant during the varying of the voltage. However, in alternative embodiments, the heat transfer gas leaks from the wafer back side region into the vacuum process chamber. In these alternative embodiments, the decreased chucking  
25      force results in increased leakage, reducing the back side gas pressure. Because the heat transfer between the wafer and the chuck is dependent upon both the distance therebetween and the heat transfer gas pressure, the rates of heat transfer by radiation, conduction, and convection are reduced in accordance with well-known principles of heat transfer.

- 30      Conversely, as the chucking voltage is increased, the electrostatic chucking force is increased and the distance between the wafer back side surface and the chuck is

correspondingly decreased. In the preferred embodiment, heat transfer gas is supplied to the wafer back side region and maintained at a relatively constant pressure during the varying of the voltage. As a result of the decreased distance between the back side surface of the wafer and the surface of the electrostatic chuck, conduction and

- 5 convection heat transfer between the wafer and the chuck is increased within the well-known parameters for such heat transfer. Furthermore, as the wafer temperature reaches approximately 400°C, radiant heat transfer is also increased, in accordance with the well-known parameters for radiant heat transfer.

In alternative embodiments in which the heat transfer gas leaks from the wafer  
10 back side region, the increased chucking force inhibits the leakage of heat transfer gas. Thus, as the gap between the wafer and the electrostatic chuck is reduced, the pressure of the back side heat transfer gas is increased. The combined effects on wafer heat transfer resulting from the increase in back side heat transfer gas pressure and the decrease in distance between the wafer and the electrostatic chuck can readily be determined by one  
15 skill in the art.

Process voltages typically depend on the temperature of the chuck and the chucking force required to hold the wafer against any back side heat transfer gas pressure. With respect to the semiconductor wafer processes disclosed herein, the present invention is operable over a chucking voltage range of from approximately 50V  
20 to 1000V and a substrate temperature range of from approximately 100°C to 900°C. A low voltage such as 50 V is generally used to attract a wafer with sufficient force to minimize wafer movement resulting from such conditions as vibration or gas flow within the chamber. A higher voltage can be used for a short period of time to flatten a bowed wafer. The preferred voltage range for the present invention is from  
25 approximately 150V to 400V, which is the voltage range generally required for an electrostatic chuck temperature of from approximately 300°C to 550°C. However, one skilled in the art will readily recognize that the concepts disclosed herein can alternatively be applied to other types of systems, substrates and processes having different temperature and voltage ranges.

30 The heat transfer gas pressure is also dependent upon the leakage rate of gas from the back side region into the vacuum process chamber. In the preferred

embodiment of the present invention, the leakage rate of back side heat transfer gas is not appreciably affected by the changes in distance between the wafer and the chuck caused by the variances in chucking voltage. However, in alternative embodiments, any resulting increase or decrease in leakage rate can easily be taken into account in

- 5 determination of the requisite process parameters by one of skill in the art using well-known scientific principles and techniques.

In the presently preferred embodiment of the present invention, a needle valve 252 is used to control the leakage rate of back side heat transfer gas into the vacuum process chamber. The needle valve is installed in a gas line 250 that connects the heat 10 transfer gas supply line 254 to the chamber. The needle valve can be opened to permit a higher leakage rate, thereby reducing the pressure of the back side heat transfer gas. Similarly, the needle valve can be closed to minimize gas leakage, resulting in increased back side heat transfer gas pressure. Because, in the presently preferred embodiment, 15 leakage of heat transfer gas is minimal, and the supply and flow rate of the heat transfer gas to the wafer back side region is relatively constant, the needle valve can be used to advantage to maintain the heat transfer gas at a relatively constant pressure not only during processing but during any varying of the chucking voltage.

In the preferred embodiment of the present invention, process qualification is used to measure the effects of the chucking voltage and/or the back side gas pressure to 20 achieve a desired wafer temperature profile. Any desired variations in chucking voltages and/or back side gas pressure are incorporated into the process recipe. The chucking voltage is supplied to the electrode(s) from the power supply 124 responsive to the power supply control module 246 as directed by the process control signals of the process control module 150. Alternatively, the chucking voltage can be manually 25 controlled, for example using a manual control 242.

In yet another embodiment, the chucking voltage is varied in response to a feedback mechanism. In this embodiment, illustrated in Figure 2, at least one parameter sensor 244, such as a temperature sensor and/or a pressure sensor, is used to measure the process conditions at the back side surface of the wafer. For example, an infrared 30 pyrometer can be used to measure the wafer temperature during processing. The measured temperature data is transmitted to a feedback control module 240 associated

with the process control module 150 and/or power supply control module 246. The process control module can then issue process control signals to modify process conditions included but not limited to the chucking voltage, back side gas pressure, heat transfer gas leakage and any combinations thereof to achieve a desired temperature or  
5 temperature profile of the wafer.

In an alternative embodiment, the recipe stored in the process control module is programmed to query a table, accessible to the process control module, that contains an appropriate voltage for a measured temperature. The same or an additional table can contain the appropriate back side heat transfer gas pressure for the measured  
10 temperature. In yet another embodiment, an intelligent software agent accessible to the process control module is used to dynamically change the chucking voltage and/or back side heat transfer gas pressure.

Varying the voltage supplied to the electrostatic chuck according to the present invention permits a rapid ramping up or down of wafer temperature. Figure 3 is a graph  
15 of wafer temperature ramp rate according to the present invention. In Test Example 310, the temperature of an electrostatically chucked wafer is increased, commencing at time zero, from approximately 210° C to approximately 400° C by manipulating the amount and flow rate of back side heat transfer gas according to the prior art. In Test Example, 320, the temperature of a wafer is similarly increased, commencing at time zero, by  
20 additionally changing the voltage supplied to the electrostatic chuck to 200V. In comparing the temperature ramp for test examples 310 and 320, it can be seen that the reduction in voltage results in a decreased rate of temperature increase.

In Test Example 330, using a different type of electrostatic chuck, the  
temperature of a wafer is increased, commencing at time zero, from approximately 200°  
25 C to approximately 400° C by manipulating the amount and flow rate of back side heat transfer gas. In Test Example 340, the temperature of a wafer is increased, commencing at time = 10 seconds, by additionally changing the voltage to 300V. A comparison of the wafer temperature ramp rate for Test Examples 330 and 340 clearly shows that the voltage increase of Test Example 340 also correspondingly increases the wafer  
30 temperature ramp rate over that for the prior art method.

- The amount and flow rate of the heat transfer gas can be varied at the same time as the chucking voltage to permit an additional level of temperature control. Figure 4 is a graph of wafer temperature vs. time vs. backside gas pressure in an aluminum planarization process according to the present invention. In the exemplary aluminum
- 5 planarization process illustrated by Figure 4, the recipe specifies that the back side heat transfer gas pressure be ramped up for a 15 second period. During the following 120 seconds, process gas supplied to the vacuum process chamber and argon heat transfer gas is supplied to the wafer back side region, followed by a 5 second period during which the argon heat transfer gas is pumped from behind the wafer into the chamber.
- 10 For each Test Example shown in Figure 4, the pressure of the back side heat transfer gas, if any, and the chucking voltage, if any is shown in Table 1:

TABLE 1

TEST EXAMPLE	HEAT TRANSFER GAS PRESSURE (in Torr)	VOLTAGE (in Volts)
410	0	0
420	2	250
430	6.5	250
440	6.5	400
450	0	250
460	4	250
470	0	400

15

A comparison of the Text Examples clearly illustrates the effects of independently varying the back side heat transfer gas pressure and the chucking voltage. The wafers of Test Examples 410, 450, and 470 were all processed without use of a back side heat transfer gas, and were attracted to the electrostatic chuck using voltages

ranging from 0 Volts to 250 Volts to 400 Volts. The graph shows that as the chucking voltage was increased, the wafer temperature ramp rate was also increased.

The wafers of Test Examples 420 and 460 were attracted to the electrostatic chuck using 250 Volts, but with respective back side heat transfer gas pressures of 2 Torr and 4 Torr. As shown by Figure 3, the wafer temperature ramp rate increased with increased backside heat transfer gas pressure. In Test Examples 430 and 440, the heat transfer gas pressure was 5 Torr and the chucking voltages were 250 Volts and 400 Volts, respectively. Figure 3 shows that the increased back side gas pressure for Test Examples 630 and 640 resulted in improved heat transfer as compared to the other Test Examples. In addition, the increase of the chucking voltage for Test Example 440 to 400 Volts further improved heat transfer, resulting in an increased wafer temperature ramp rate as compared to the other Test Examples.

The variations in wafer temperature ramp rate that can be achieved using the present invention can be of advantage in numerous processes. In the example of aluminum planarization, the voltage can be increased at the completion of the seed layer deposition step to rapidly ramp up the wafer temperature for the fill step. Variation of the wafer temperature ramp rate can additionally be of advantage in an annealing process, to minimize the effects of outgassing, and to increase or decrease the absorption of ions or molecules by the wafer.

The varying of chucking voltage according to the present invention can also be used to control the time required to perform a particular step or process. For example, the diffusion of metal through barriers is time and temperature dependent. By rapidly ramping the wafer temperature, the required time for the diffusion process can be correspondingly decreased. As a result, the amount of diffusion is reduced. In addition, for a deposition process, the amount of time during which the process is performed is a factor in the deposition thickness. The invention can therefore be used to increase or decrease the thickness of deposited layers by varying the chucking voltage to modify the wafer temperature ramp rate.

One skilled in the art will readily recognize that the chucking voltage and/or back side gas pressure can be varied as appropriate in accordance with the process recipe. For example, while an aluminum planarization process is commenced at a lower temperature

and then ramped up to a higher temperature, the present invention can also be applied to processes that commence at a higher temperature that is subsequently reduced. In addition, the chucking voltage can be increased or decreased any number of times and to any appropriate voltage level as required by the particular process.

- 5 By decreasing the voltage supplied to the electrostatic chuck, the time required to dechuck a wafer can be reduced. This can be of advantage in decreasing wafer throughput time for the fabrication process. Figure 5 is a graph of electrostatic chuck backside gas pressure and dechucking time for various chucking voltages according to the present invention. In this example, a boron silicate glass deposition process  
10 ("BSGP") is performed at varying chucking voltages and using varying back side heat transfer gas pressures 510. It can be seen from Figure 5 that as the chucking voltage increases from approximately 175 Volts, the time to dechuck the wafer also increases.

Although the present invention has been described with reference to specific exemplary embodiments, it will be evident that various modifications and changes may  
15 be made to these embodiments without departing from the broader spirit and scope of the invention as set forth in the claims. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

- For example, in the preferred embodiment, the method and system according to the present invention is used with an electrostatic chuck with having a grooved surface.  
20 However, the method and system described herein can also be used with an electrostatic chuck having any other appropriate surface configuration.

The method according to the present invention can be used not only to modify substrate temperature, but to maintain a selected substrate temperature. For example, a higher chucking voltage and higher back side heat transfer gas pressure can be used at  
25 the commencement of a process until a desired substrate temperature is achieved. The voltage and/or gas pressure can thereafter be varied to maintain this substrate temperature.

What is claimed is:

1. A method for controlling temperature of a substrate during processing, comprising the steps of:
  - 5        using a voltage to electrostatically attract the substrate to an electrostatic chuck disposed on a pedestal such that the back side surface of the substrate is at a specified distance from a surface of the electrostatic chuck; and  
              varying the voltage during at least one processing step to change the distance between the substrate back side surface and the surface of the electrostatic chuck.
- 10      2. The method of claim 1, further comprising the step of supplying a heat transfer gas between the substrate and the electrostatic chuck.
- 15      3. The method of claim 2, further comprising the steps of:
  - measuring the temperature of the substrate; and  
              varying the voltage in response to the measured temperature.
- 20      4. The method of claim 2, further comprising the steps of:
  - disposing at least one heater within the pedestal; and  
              transferring heat to the substrate from the heater.

5. A method for controlling the temperature of a wafer during a metal deposition process, comprising the steps of:
  - supporting, in a vacuum process chamber, a wafer on a pedestal including an electrostatic chuck, the pedestal having a heater disposed therein;
  - 5 supplying a voltage to the electrostatic chuck to electrostatically attract the wafer to the electrostatic chuck, thereby creating a gap between the wafer back side surface and the surface of the electrostatic chuck;
  - transferring heat from the heater to the wafer;
  - performing a metal deposition process on the wafer;
  - 10 supplying a heat transfer gas to the gap; and
  - varying the voltage to re-size the gap between the wafer and the electrostatic chuck during the metal deposition process;
  - wherein the temperature of the wafer is controlled.
- 15 6. The method of claim 5 further comprising the step of varying the pressure of the heat transfer gas independently of the varying of the voltage.
7. The method of claim 5 wherein the metal deposition process is aluminum planarization.
- 20 8. The method of claim 5, further comprising the steps of:
  - measuring the temperature of the wafer; and
  - varying the voltage in response to the measured temperature.
- 25 9. The method of claim 8, further comprising the step of controlling the pressure of the heat transfer gas independently from the varying of the voltage and in response to the measured temperature.

10. A system for controlling temperature of a substrate during processing in a vacuum process chamber comprising:

an electrostatic chuck disposed within the vacuum process chamber;

a power supply for supplying power to the electrostatic chuck to attract the

5 substrate thereto at a distance;

a power supply control module in communication with the power supply; and

10 a process control module for issuing process control signals to the power supply control module to vary the power supplied to the electrostatic chuck from the power supply during at least one processing step to change the distance between the substrate and the electrostatic chuck.

11. The system of claim 10, further comprising:

15 a heat transfer gas source for supplying a heat transfer gas between a back side surface of the substrate and the electrostatic chuck; and

15 a heat transfer gas control for controlling the supply of heat transfer gas.

12. The system of claim 10, further comprising:

20 a temperature measurement device for measuring the temperature of the substrate; and

20 a feedback control module for providing the measured substrate temperature to the process control module;

wherein the power supply control issues a process control signal in response to the measured substrate temperature.

13. An aluminum planarization processing system, comprising:

a vacuum process chamber;

a pedestal disposed within the vacuum process chamber;

an electrostatic chuck disposed on the pedestal for supporting and retaining a

5 wafer;

a power supply for supplying a voltage to the electrostatic chuck to retain the wafer at a first distance from the chuck; and

10 a power supply control module for adjusting the voltage supplied by the power supply during at least one processing step to retain the wafer at a second distance from the chuck.

14. The electrostatic chuck of claim 13, further comprising:

a sensor for measuring the temperature of the wafer;

a processor in communication with a first memory, the first memory including a

15 set of instructions for adjusting the voltage in response to the measured temperature; and

a feed back control module for providing the measured temperature to the processor.

15. The electrostatic chuck of claim 13, further comprising a gas supply for supplying a

20 heat transfer gas between the wafer and the pedestal.

16. The electrostatic chuck of claim 15, further comprising a gas supply control module.

17. The electrostatic chuck of claim 16 further comprising a second memory accessible

25 to the processor, the second memory including a set of instructions for adjusting the heat transfer gas pressure in response to the measured temperature.

18. A method for controlling substrate temperature in a vacuum process chamber, comprising the steps of:

supplying a first voltage to electrostatically hold the substrate at a first distance from a chuck disposed within the vacuum process chamber such that at least a portion of  
5 the substrate is maintained at a first temperature; and

changing the first voltage to a second voltage to electrostatically hold the substrate at a second distance from the chuck, such that the portion of the substrate is maintained at a second temperature.

10 19. An article of manufacture prepared by a method comprising the steps of:

supporting, in a vacuum process chamber, a wafer on a pedestal containing an electrostatic chuck;

supplying a voltage to the electrostatic chuck to attract the wafer to the electrostatic chuck;

15 processing the wafer in the vacuum process chamber; and

varying the voltage in association with the wafer processing to change the distance between the substrate and the pedestal to control wafer temperature.

20 20. The article of manufacture of claim 19, wherein the method further comprises the

step of supplying a heat transfer gas between a back side surface of the wafer and the electrostatic chuck.

21. The article of manufacture of claim 20, wherein the method further comprises the

step of varying the pressure of the heat transfer gas independently of the varying of the

25 voltage.

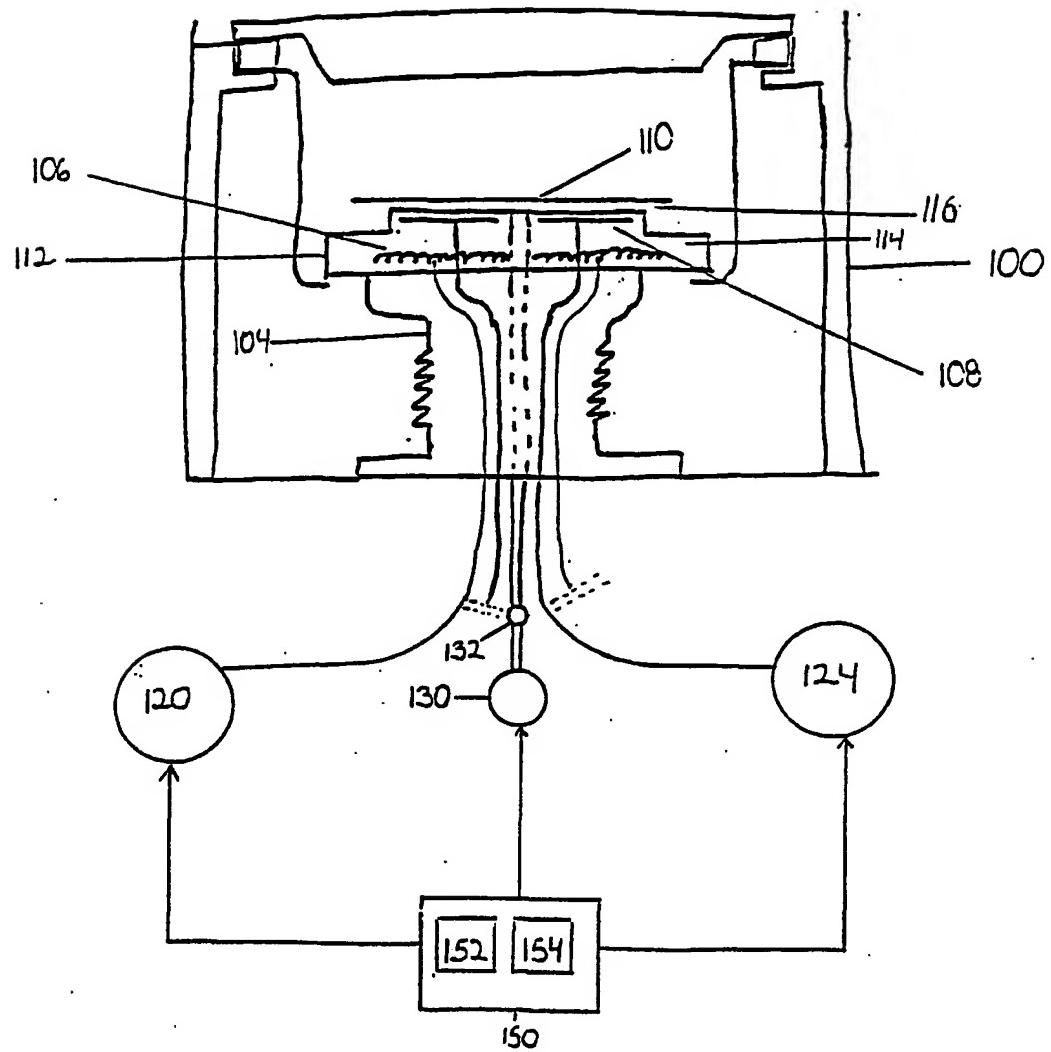


FIGURE 1

(PRIOR ART)

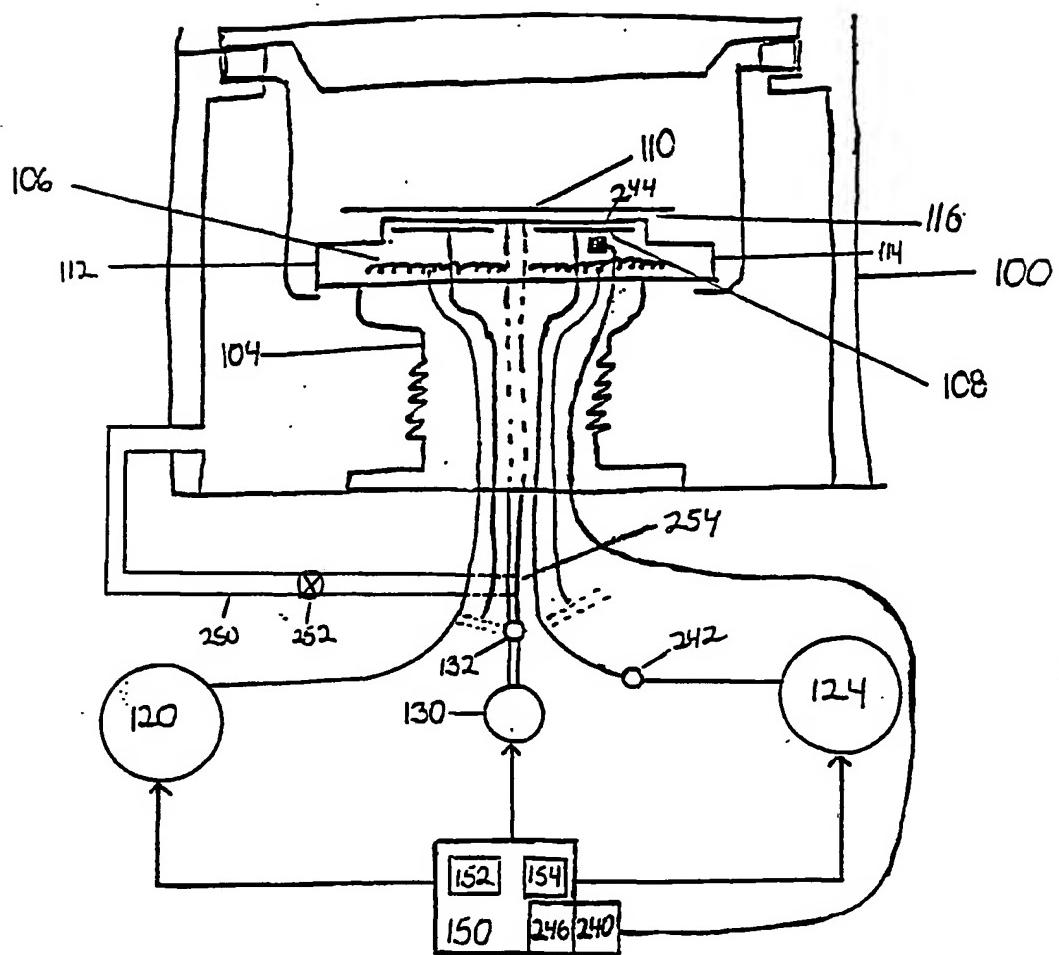


FIGURE 2

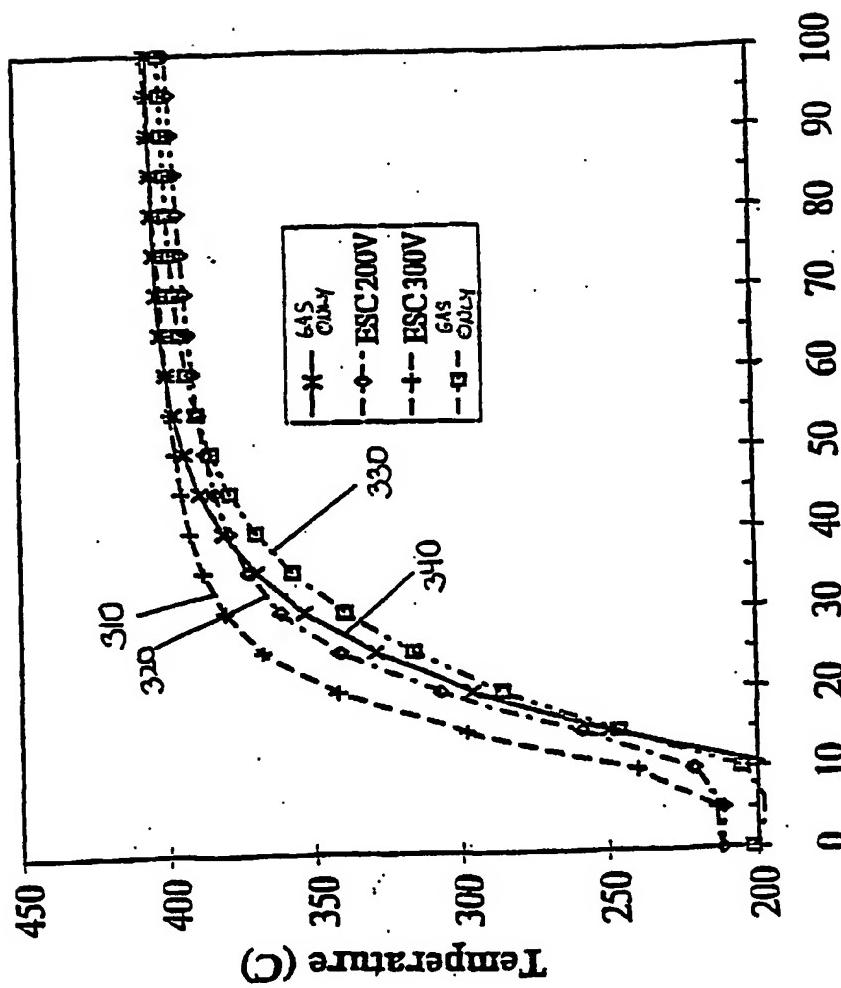


FIGURE 3

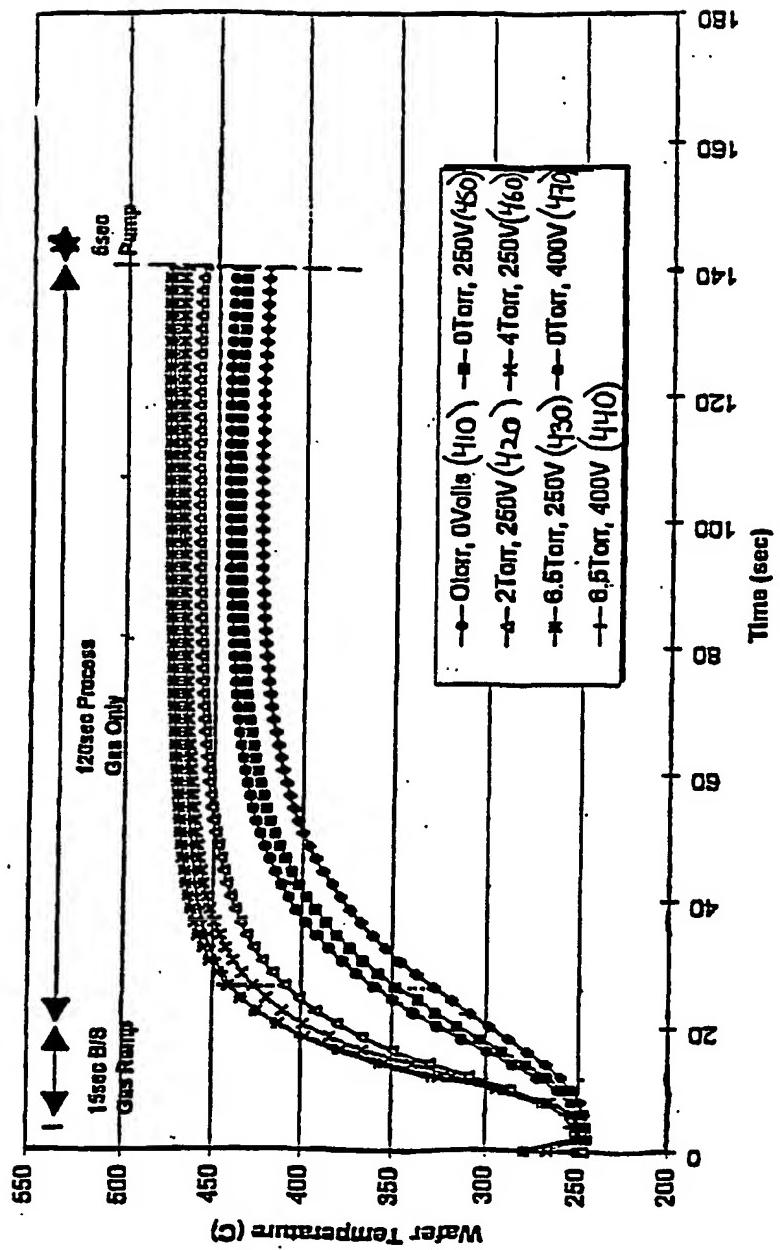


FIGURE 4

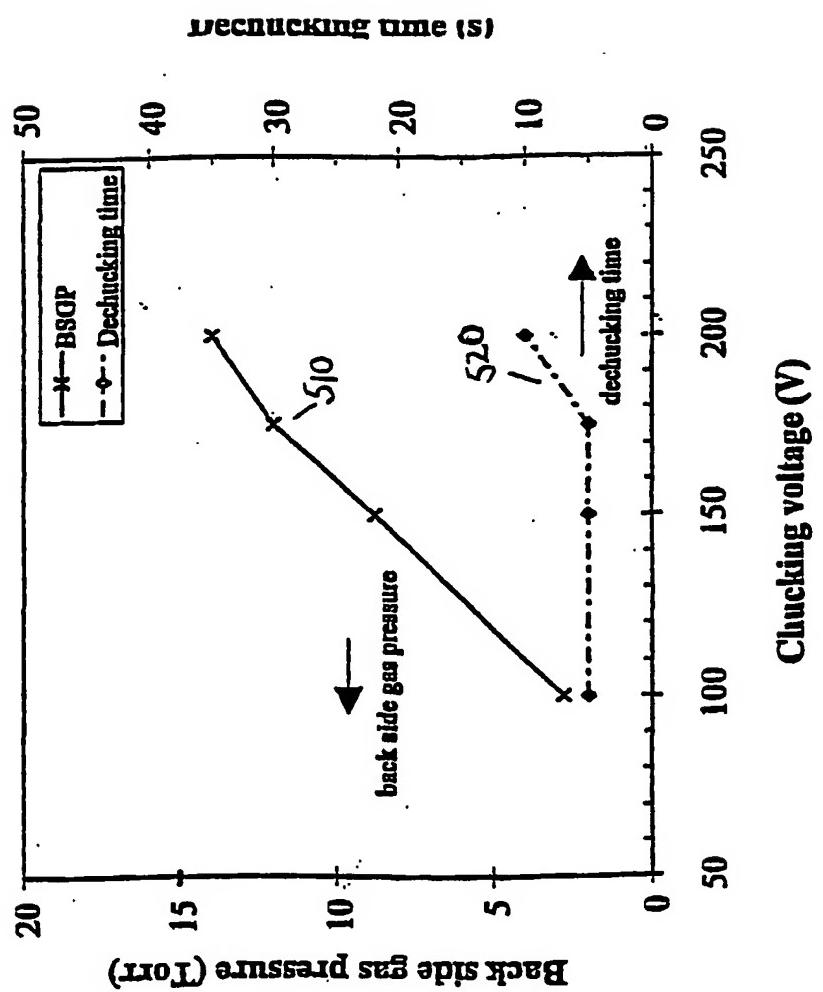


FIGURE 5

## INTERNATIONAL SEARCH REPORT

II      International Application No  
PCT/US 01/41838

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7    H01L21/68    H01L21/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7    H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 675 471 A (KOTECKI DAVID EDWARD) 7 October 1997 (1997-10-07)  column 3, line 45 - line 65 column 15, line 64 -column 16, line 29 column 19, line 38 - line 67	1-3,5,6, 8-13,15, 16,18-21
X	EP 0 693 774 A (IBM) 24 January 1996 (1996-01-24)  column 1, line 9 - line 14; claim 8 column 2, line 13 - line 18 column 6, line 43 - line 49 column 7, line 2 - line 5 column 7, line 25 - line 30 column 8, line 15 - line 20  ---	1-3,5,6, 8-13,15, 16,18-21

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

## \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*&\* document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 December 2001	20/12/2001
Name and mailing address of the ISA  European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer  Ahlstedt, M

## INTERNATIONAL SEARCH REPORT

Int. Application No  
PCT/US 01/41838

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 880 923 A (HAUSMANN GILBERT) 9 March 1999 (1999-03-09)  column 1, line 29 - line 53 column 5, line 53 - line 63; claims 3,12,13 ---	1,2,4,5, 8,10-13, 15,18-20
A	WO 00 19519 A (LAM RES CORP) 6 April 2000 (2000-04-06)  page 32, line 29 -page 33, line 7 ---	1,2,5, 10,13, 15,18-20
A	WO 99 52144 A (APPLIED MATERIALS INC) 14 October 1999 (1999-10-14) page 21, line 30 - line 33 ---	
A	US 5 777 838 A (FUKUNISHI RYUICHI ET AL) 7 July 1998 (1998-07-07) column 6, line 9 - line 59; claim 1 -----	

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No  
PCT/US 01/41838

Patent document cited in search report		Publication date		Patent family member(s)	Publication date
US 5675471	A	07-10-1997	US EP JP	5548470 A 0693774 A2 8055905 A	20-08-1996 24-01-1996 27-02-1996
EP 0693774	A	24-01-1996	US EP JP US	5548470 A 0693774 A2 8055905 A 5675471 A	20-08-1996 24-01-1996 27-02-1996 07-10-1997
US 5880923	A	09-03-1999	TW WO	395006 B 9857371 A1	21-06-2000 17-12-1998
WO 0019519	A	06-04-2000	US AU TW WO	6125025 A 5913699 A 426930 B 0019519 A1	26-09-2000 17-04-2000 21-03-2001 06-04-2000
WO 9952144	A	14-10-1999	US WO US	6198616 B1 9952144 A1 6304424 B1	06-03-2001 14-10-1999 16-10-2001
US 5777838	A	07-07-1998	JP	9172055 A	30-06-1997